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ABSTRACT

This instructor's guide contains materials that are intended for use as part of the regular auto mechanics curriculum and that provide information necessary to convert a gasoline engine with a niminum of modifications to successfully be operated on ethanol alcohol. It accompanies a student guide that is available separately. Contents include a summary sheet with an introduction, objectives, a list of needed teaching/learning materials, suggested instructional methods, references, and suggested activities; an activity sheet with answers; student evaluation with answers; a performance evaluation sheet; information sheets with photographs and diagrams; and additional reference material. (YLB)

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INSTRUCTOR'S GUIDE

CONVERSION OF GASOLINE ENGINES TO USE ETHANOL AS THE SOLE FUEL

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MODULE _____

INSTRUCTOR'S GUIDE

PROGRAM: _____

UNIT TITLE: _____

MODULE TITLE: _____

Information X **Demonstration** X **Length of Presentation** ____

INTRODUCTION:

The anxiety over accessibility of world oil supplies in recent years has renewed interest in possible use of domestic ethanol alcohol as a motor fuel. Research carried out at SFCC in 1980 yielded a system which makes it possible to operate existing internal combustion engines on ethanol as the sole fuel. This program is designed to provide information necessary to convert an engine with a minimum of modifications to successfully be operated on ethanol alcohol as the sole fuel.

This program is intended for use as part of the regular auto mechanics curriculum. No basic engine or fuel system theory will be present, only components affected by the conversion to ethanol fuel will be included

Some basic material may be included for reference purposes.

OBJECTIVES

1. Compare the characteristics of gasoline and ethanol as motor fuel.
2. Explain the problems involved in using ethanol in an engine designed to run on gasoline.
3. Explain adjustment and modification necessary to compensate for ethanol fuel.
4. Demonstrate how to fabricate parts needed to modify carburetor venturi to vaporize ethanol.
5. Describe how to check ethanol to determine proof value.

TEACHING/LEARNING MATERIALS: (Number Included)

X **Student Packet**	_____ **Video Tape**
X **Instructor's Guide, Key, and Script**	_____ **Film Loop**
_____ **Slide/Tape Presentation**	_____ **Cassette Tape**

Sheet aluminum--suggest start with .032 thickness
Heavy paper--to make pattern for sleeves
Training carburetors
Vehicle for conversion

INSTRUCTIONAL METHODS SUGGESTED:

Students should construct paper patterns of the sleeves and fit them to the training carburetors before transferring them to the aluminum sheet for construction of the finished sleeve. Instructions for making the sleeve patterns are included in the student guide. As some trial and error will be involved in areas such as sleeve thickness, spark plugs, timing etc., it is suggested the instructor make the necessary modifications and adjustments on a training engine or operational vehicle. Demonstration of these procedures should be performed by the instructor to enhance student learning.

REFERENCES

Elements of Steam and Gas Power Engineering, by Potter and Calderwood. McGraw-Hill Book Co. 1924

Power Alcohol and Farm Relief, by Leo M. Christensen Ph. D., Ralph M. Hixon Ph. D., Ellis I. Fulmer Ph. D. Iowa State College 1934. Published by The Chemical Foundation, 654 Madison Avenue, New York, N.Y.

SUGGESTED ACTIVITIES:

The following laboratory activities are included to enhance student learning and participation:

1. Construct a paper pattern of the venturi sleeve and fit to a carburetor venturi.
2. Cut an aluminum sleeve using paper pattern and fit to carburetor venturi.
3. Install modified carburetor on training engine or operational vehicle and make necessary adjustments.

EVALUATION: (See attached sheets)

____ **ORAL** X **WRITTEN** X **PERFORMANCE**

ACTIVITY SHEET

ENGINE CONVERSION TO ETHANOL

Instructions: Complete the questions and laboratory activities on this activity sheet. You may refer to the information sheets while completing this exercise.

1. In a short paragraph explain the effects on the carburetor fuel metering system when the venturi diameter is changed. The air-fuel ratio is enriched as the venturi diameter is made smaller and leaned as the venturi diameter is increased.

2. In order to get acceptable performance and economy from a vehicle operating on ethanol an average air-fuel ratio of about 9-1 is required.

3. Anhydrous or neat alcohol is pure. If it is rated as 190 proof it means it contains water.

4. With respect to fuel the octane rating indicates. Anti knock value determined by rate of burn.

5. The most difficult problem to overcome in using ethanol as fuel in a low compression engine is: getting it to vaporize.

6. Comparing ethanol to gasoline as a motor fuel, ethanol contains about seventy per cent as much heat as gasoline.

Ask your instructor for access to a training engine or vehicle and the necessary tools and supplys to convert the unit to operate on ethanol.

STUDENT EVALUATION

ENGINE CONVERSION TO ETHANOL

Instructions: Before taking this test you must have completed the tasks on the activity sheet.

1. One B.T.U. equals: The amount of heat to raise the temperature of one pound of water one degree F.

2. To achieve a combustable mixture in an engine the air fuel ratio with ethanol must be richer than with gasoline.

3. The B.T.U. of heat available in ethanol are about seventy percent as much as in gasoline.

4. The air-fuel ratio for gasoline in an engine runs about 15-1 while with ethanol it is about 9-1.

5. How does decreasing the size of the carburetor venturi enrichen the fuel mixture. Lowers the pressure in the ventrui causing more fuel to enter the engine.

6. What problem can be caused in a fuel system that has been previously run on gasoline when converted to run on ethanol? The loosening of deposits left by gasoline.

PERFORMANCE EVALUATION

Instructions: This section is for the instructor to evaluate the quality of the task of converting an engine to run on ethanol.

	Unexceptable	Satisfactorily	Excellent
1. Venturi Sleeve Construction			
2. Venturi Sleeve Installation			
3. Engine Starting			
4. Engine Idle			
5. Engine Acceleration			
6. Engine Power			

STUDENT EVALUATION

ENGINE CONVERSION TO ETHANOL

Instructions: Before taking this test you must have completed the tasks on the activity sheet.

1. One B.T.U. equals: _____

   _____

   _____

2. To achieve a combustable mixture in an engine the air fuel ratio with ethanol must be _____ than with gasoline.

3. The B.T.U. of heat available in ethanol are about _____ _____ as much as in gasoline.

4. The air-fuel ratio for gasoline in an engine runs about _____ while with ethanol it is about _____.

5. How does decreasing the size of the carburetor venturi enrichen the fuel mixture. _____

   _____

   _____

6. What problem can be caused in a fuel system that has been previously run on gasoline when converted to run on ethanol? _____

   _____

INFORMATION SHEETS

The problem of getting an engine designed to operate on gasoline to run on ethanol requires an understanding of the basic differences in the two fuels.

An internal combustion engine is a heat engine. The heat value of a gallon of gasoline is about 124,800 Btu while for ethanol it is about 84,400 Btu. Gasoline vaporizes at 140° to 160° F, kerosene at 250° to 400° F, while ethanol vaporizes at 180° to 200° F. The flash point of gasoline is -50° F, alcohol 70° F, the auto ignition temperature for gasoline is 495° F, for alcohol 685° F.

Some other comparisons are presented in the appendix.

A few important differences require consideration when substituting one fuel for the other. The air fuel ratio for gasoline is 14.2-15.1 in most stock carburetors. Ethanol requires an air fuel ratio of 9.0-1.

Alcohol is much more difficult to vaporize than gasoline. It requires 900 Btu to vaporize 1 gallon of gasoline and 3,378 Btu to vaporize 1 gallon of alcohol. When gasoline is vaporized as in a carburetor, the mixture will be about 38° F cooler than the liquid and air before vaporization. Alcohol will have a temperature drop of 143° after vaporization.

The net effective calorific value of alcohol is very nearly 70 per cent that of gasoline. This includes the latent heat of evaporation of the fuel and not that of the water formed in the combustion. The thermal efficiency with which alcohol is used in an engine at any compression ratio is always somewhat greater than that with which gasoline is used in the same engine, due allowance being made for different requirements in a fuel ratio.

At a low compression pressure, suitable for use with gasoline, the power output of a given engine is about 10 to 20 percent greater with alcohol as the fuel, and the specific fuel consumption of the alcohol is about 40 percent greater than that of gasoline. The increase in power output is to a large extent, due to the higher latent heat of the alcohol, as compared with gasoline. The alcohol which produces a greater lowering of temperature upon evaporation. The result is a cooler denser air fuel mixture, and a greater charge of air and fuel is taken into the cylinder during the intake stroke.

The vapor pressure of alcohol is lower than gasoline, and the latent heat of evaporation is higher. As a result it is harder to start a cold engine on alcohol than on gasoline.

The most practical way to overcome this problem is to devise some type of priming system to inject gasoline into the engine for cold starting.

Engine operation is smoother and steadier on alcohol than on gasoline. This characteristic has been called the "steam engine" effect. The engine shows an ability to operate under heavy load and at low speed, with full throttle, without "bucking" which characterizes similar conditions with gasoline as the fuel. It has been thought that a slightly lower rate of flame propagation may in part, account for this result.

Alcohol burns in an engine without leaving a residue of carbon. In addition, alcohol acts as a solvent for the binder in the carbon deposit left by the combustion of gasoline and, therefore, serves to loosen such carbon accumulation.

The products of combustion of alcohol in an engine are essentially the same as those from the combustion of gasoline, but the carbon monoxide content is lower. The flame temperature, with alcohol as the fuel, is appreciably lower than with gasoline.

Alcohol has a higher density, lower fluidity, and requires a lower air-fuel ratio (richer mixture) than does gasoline. Hence, to adapt a gasoline engine to burn alcohol some modifications of the carburetor systems must be accomplished.

From the preceding information, it can be seen that alcohol is, in many respects, an excellent fuel for spark ignition motors. The low vapor pressure and high latent heat causing cold starting difficulties is somewhat offset by the fact that alcohol and air form combustible mixtures over a wider range of concentrations than does gasoline. These same properties make alcohol a safer fuel to handle. Alcohol mixes with water in all proportions, so that alcohol fires are readily extinguishable by water. It is evident, that alcohol, or blends consisting principally of alcohol, cannot be used interchangeably with gasoline, although such fuels may be very satisfactory in engines designed to use them.

The heat content of a fuel is not of itself of great importance, but taken in conjunction with thermal efficiency, it gives a measure of fuel consumption. The heat contents of the correct air-fuel mixtures are practically the same for most fuels, about 80 Btu per cu. ft. The latent heat of evaporation is an important factor in carburetion. The correct air-fuel mixture, with alcohol is 143° F colder than the original air and fuel, while the corresponding value for gasoline is only 38.8° F and a blend of 20% alcohol and 80% gasoline results in a 55.6° temperature drop. The cooler air-fuel mixture obtained with alcohol results in a denser charge entering the cylinder.

In the carburetor, the fuel and air are so proportioned as to produce a mixture which gives as complete combustion as is consistent with good performance.

The air-fuel ratio can be varied, and the effect of such variation upon power and economy is accepted. The air-fuel ratio required for alcohol is about 60% that for gasoline. Since air-fuel ratios are affected by the density and humidity of the air, it is not possible to make very fine adjustments. The usual practice is to use a lower air-fuel ratio, that is a richer mixture, than the most economical one.

In the automotive engine, the air-fuel ratio must be varied to adjust for changes in engine speed and temperature. Alcohol forms explosive mixtures over a much wider range of proportions that does gasoline. The air-fuel ratio has a very great influence upon the degree of completeness of combustion. The lower the air-fuel ratio, the greater the carbon monoxide content of the exhaust gases.

It is highly desirable that neither the fuel nor its products of combustion have a deleterious effect upon any part of the engine or fuel system. The products of combustion of a hydrocarbon or of an alcohol are acidic, and are therefore somewhat corrosive. This condition is particularly pronounced when low air-fuel ratios are used, and is believed that much excessive wear of the upper part of the cylinder bore is due to the use of too rich mixture. The products of combustion of alcohol are the same as those of gasoline, and the exhaust gases are no more corrosive. Gasolines may sometimes contain amounts of sulfur and cause corrosion due to the formation of sulfuric acid. Alcohol contains no such corrosive materials. The gums formed by gasoline are soluble in alcohol, and are removed from the walls of tanks which have previously contained gasoline.

If large amounts of gum or residue are present, particles are loosened and collect in fuel filters or screens. Special accomodation should be made for this situation during early stages of converting to alcohol fuel.

In summary, alcohol would seem to be an acceptable fuel. Some increase in consumption is in part offset by greater thermal efficiency, a slight increase in power, smoother operation and lower operating temperatures. The conversion to alcohol fuel requires overcoming the difficulty in vaporizing the alcohol in the carburetor. The Spignesi-Mishler system to achieve this is next presented.

THE SPIGNESI - MISHLER SYSTEM

After some experimentation with enlarging carburetor jets and so on, as employed by most gasoline to alcohol conversion methods, it was abandoned in favor of modification of the air flow system. The reason for this change was the fact that the liquid systems in the carburetor are precisely calibrated by the manufacturer and are independent of operator control. Air flow, which determines the speed and power output of the engine, is under the control of the operator and can be varied under a wide range of speed and load requirements without upsetting the basic function of the carburetor.

The desired results can be achieved by concentrating on the air flow in the venturi, while at the same time leaving the liquid system intact. By installing a sleeve in the venturi there will be a slight increase in the restriction of the air flow. This increase in restriction will cause an increase in velocity of the air passing through. The higher velocity of the air will achieve better vaporization of the alcohol and will result in a change in the air fuel ratio from 15 to 1 to about 9 to 1.

The success of the conversion can be noted by checking the temperature of the carburetor base while the engine is operating. Considerable lowering of temperature should be evident. Some frost may appear at times. If there is not evidence of these conditions and engine performance is not satisfactory the thickness of the material used in making the sleeves may need to be adjusted. The vehicles used in our experiments required .032 thick aluminum for the sleeves. This resulted in a 12 per cent reduction in the area of the venturi. Vehicles of other displacement and carburetor configuration may require different thickness for the sleeves. This can be determined by trial and error until satisfactory engine performance is achieved.

The following pages contain detailed instructions on making the sleeves. Care must be taken not to obstruct any discharge ports or air bleed orifices in the venturi area. Holes can be drilled in the sleeve to relieve these openings.

Instructions are also included for a gasoline priming system. For a vehicle operating in various temperatures and weather conditions it would be desirable to construct this system to insure ease in starting under all conditions.

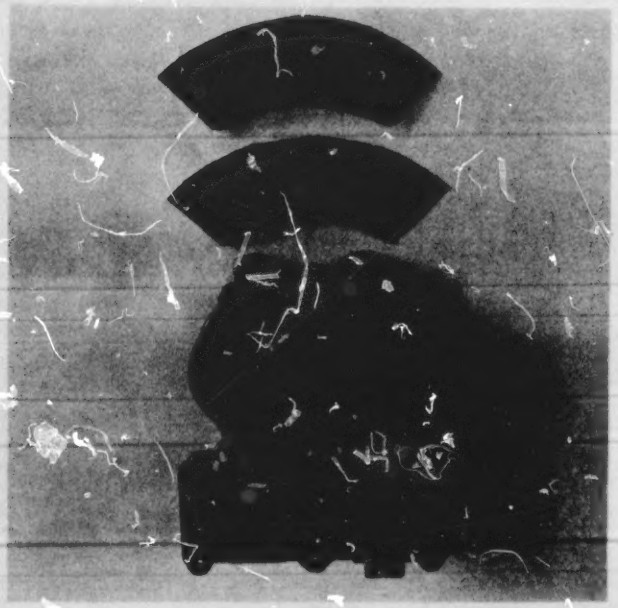


Fig. 1 Venturi Sleeve Patterns

Pattern for venturi sleeve is first made of paper. Use venturi of carburetor to be converted as guide.

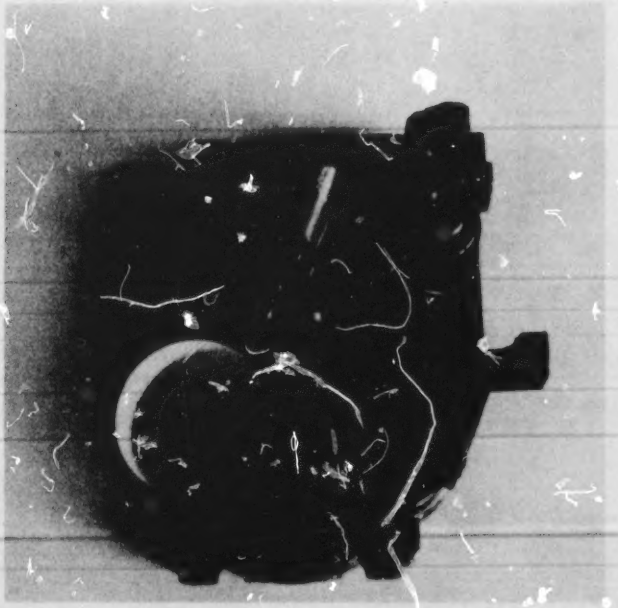


Fig. 2 Paper Pattern in Venturi

Trim pattern until satisfied with fit in carburetor venturi.

Fig. 3 Fitting Aluminum Sleeve to Carburetor

Cut out aluminum sleeve using paper pattern as guide. Again trim aluminum sleeve until satisfied with fit.

Fig. 4 Aluminum Sleeve in Venturi

Aluminum sleeve should fit with bottom flush with surface, ends fit together and top should extend about 1/8" above top of venturi.

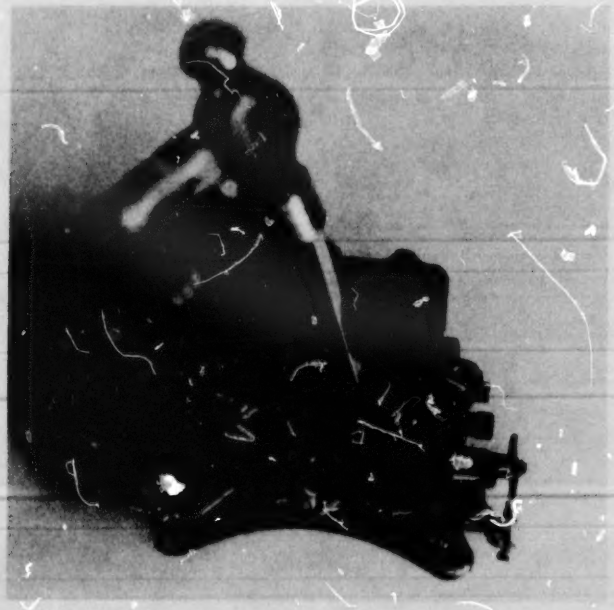


Fig. 5 Forming Top of Sleeve

Top of sleeve should be bent over using a pin punch forming them to the shape of the top of the carburetor venturi.

GASOLINE INJECTION SYSTEM

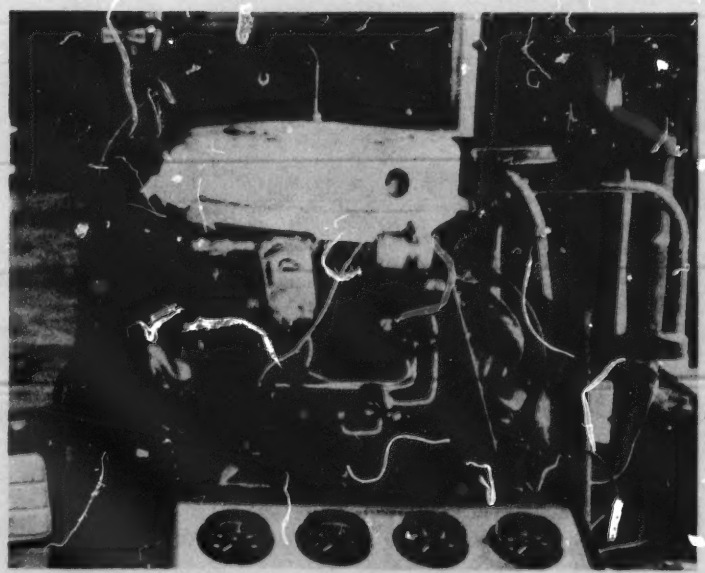
To prevent starting difficulty, particularly in cooler weather, it is recommended some type of gasoline injection system be installed.

The system shown consists of a small engine fuel tank attached to an electric fuel pump with a fuel filter between. A line running to the air filter injects gasoline through a tube with an orifice directly into the air horn of the carburetor. The control system consists of a horn button wired to a horn relay to the pump. An oil pressure switch teed into the output line wired to an indicator light, serves to signal when gasoline is being delivered to the carburetor air horn.

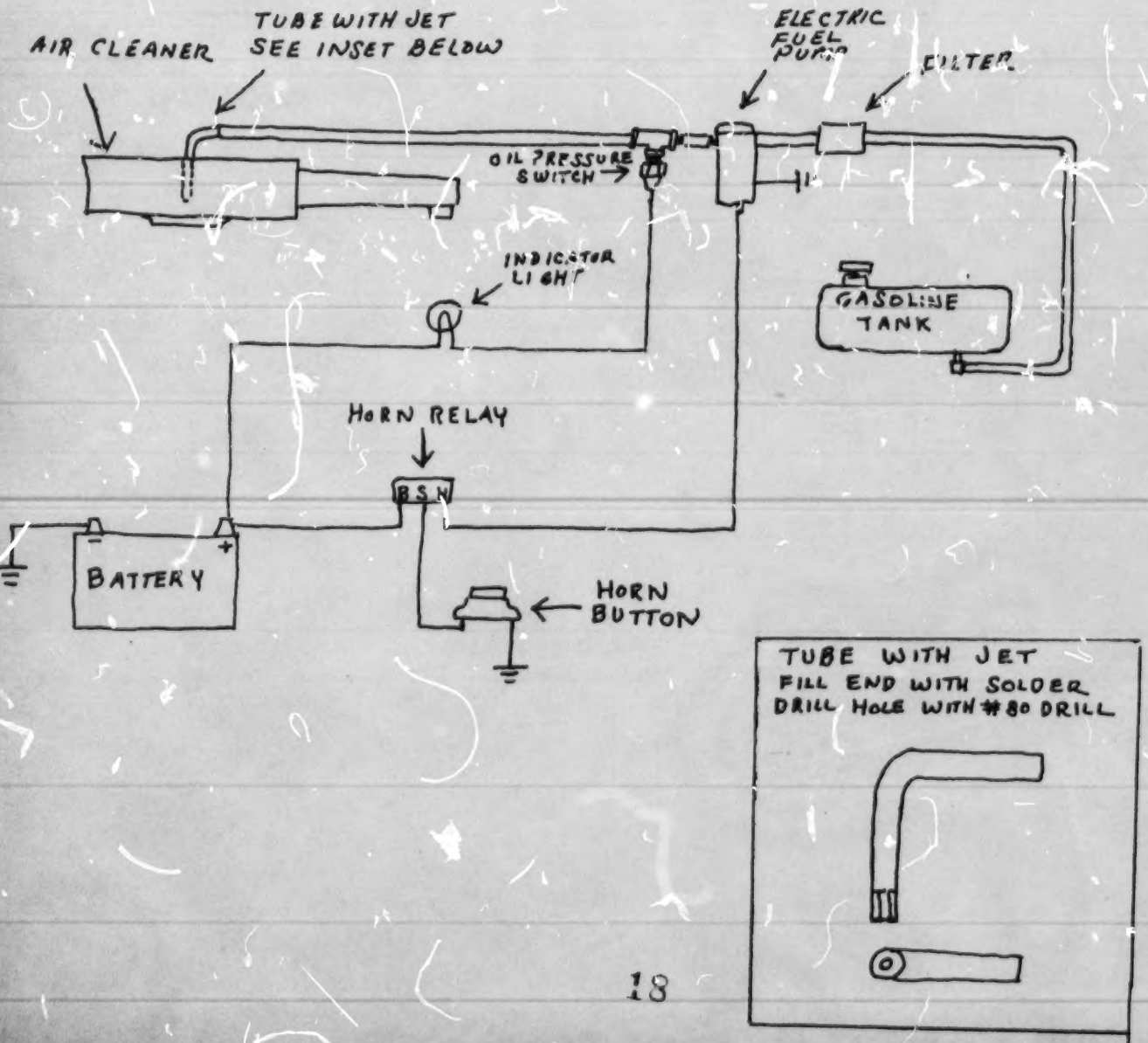
A list of the parts required and construction details can be found on the following pages.

PARTS LIST

1. Electric Fuel Pump
2. Horn Relay
3. Horn Button
4. Oil Pressure Switch
5. Indicator Light
6. In-line Fuel Filter
7. Small Fuel Tank (1 gallon or less)
8. 1/8" x 2" Pipe Nipple
9. 1/8" Pipe Tee
10. 1/4" Fuel Hose
11. 10" of 1/4" Steel or Copper Tube
12. 16 Ga. Primary Wire
13. No. 80 Twist Drill (.013)



GASOLINE INJECTION SYSTEM DIAGRAM



CHECKING ETHANOL FOR PROOF VALUE

The quickest and most common method employed in determining specific gravity of liquids is by using a hydrometer. The hydrometer is usually a sealed glass tube with an enclosed scale in a cylindrical stem and a bulb weighted with mercury or shot at the bottom. The depth to which a given hydrometer will float in a liquid is determined by the specific gravity of the liquid. The hydrometer will sink to that level which will cause it to displace an amount of liquid whose weight exactly equals that of the instrument. Because the depth at which the instrument floats is inversely proportional to the specific gravity of the liquid, as a scale which reads specific gravity directly can be mounted vertically along the instrument. Hydrometers are available for various commercial uses. They are used to measure the spceific gravity of alcohols, gasoline, other petroleum products, acids, sugar solutions, etc.

Obtain the proper instrument to be used for alcohol. Tables are available to convert the specific gravity scale to a proof value. Anhydrous or neat alcohol is pure, it contains no water. Pure alcohol is rated at 200 proof. Alcohol that measures 190 proof would contain five per cent water. The carburetor modifications herein described were developed using alcohol in the 187 - 190 proof range.

PROPERTIES OF ETHANOL, GASOLINE AND WATER

CHEMICAL PROPERTIES	Gasoline	Ethanol	Water
Formula	C_4-C_{12}	CH_3CH_2OH	H_2O
Molecular Weight	varies	46.1	18.015
% Carbon (by weight)	85-88	52.1	
% Hydrogen (by weight)	12-15	13.1	
% Oxygen (by weight)	indefinite	4.7	
C/H ratio	5.6-7.4	4.0	
Stoichiometric Air-to-Fuel Ratio	14.2-15.1	9.0	
PHYSICAL PROPERTIES	**Gasoline**	**Ethanol**	**Water**
Specific Gravity	0.70-0.78	0.794	1.0
Boiling Point (^{o}F)	80-440	173	212
Freezing Point (^{o}F)	-70 approx.	-173	32
Viscosity at 68^{o}F (cp)	0.288	1.17	1.0
THERMAL PROPERTIES	**Gasoline**	**Ethanol**	**Water**
Heating Value			
Btu/lb at 68^{o}F	20,260	12,800	
Btu/gal	124,800	84,400	
Heat of Vaporization			
Btu/lb	150	396	940
Btu/gal	900	3,378	7,802
Octane Ratings			
Research	91-105	106-108	
Pump (Ron + Mon)/2	86-90	98-100	
Flammability Limits (% by volume in air)	1.4-7.6	4.3-19.0	
Specific Heat (Btu/lb - ^{o}F)	0.48	0.60	1.0
Autoignition Temperature (^{o}F)	430-500	685	
Flash Point (^{o}F)	-50	70	

CONVERSION FACTORS

1 gallon gasoline = 6.2 pounds per gallon
1 gallon water = 8.33 pounds (at 60° F) = 0.134 cubic foot = 128 fluid ounces = 4 quarts = 8 pints = 3.785 liters
1 gallon of ethanol weighs 6.6 pounds
1 barrel of crude oil = 42 gallons
1 Btu = 252 calories = heat required to raise 1 lb of water 1 degree Fahrenheit (°F)
1 bushel = 56 pounds
1 calorie = .00397 Btu = heat required to raise 1 gram of water 1 degree Centigrade (°C)
1 U.S. liquid gallon = 4 quarts = 231 cubic inches = 3.78 liters
8 gallons = 1 bushel
1 liter = 1.057 U.S. liquid quarts
1 fluid ounce = 30 milliliters
1 pound = 453.6 grams
1 cubic foot = 7.48 liquid gallons = 62.36 pounds H_2O (at 60°F)
1 acre = 43,560 square feet = 4,840 square yards
To convert from °F to °C, subtract 32 and then multiply by 5/9.
To convert from °C to °F, multiply by 9/5 and then add 32

REFERENCE MATERIAL

Principles of Internal Combustion Engines

The term combustion engines originally designated all engines which utilized the combustion principle to convert the energy stored in fuel into mechanical power. Similarly, fuel meant anything which could be exploded, and in the beginning some rather weird engines were designed. In France in the 1680's gunpowder was tried as a fuel.

The first real gas engine was proposed in England in 1794. It was to be driven by a flame-ignited explosive mixture of vaporized spirits of turpentine and air. In 1820 an actual gas engine was built operating on a hydrogen-air mixture. These engines were monstrous. The combustible mixture was exploded below the piston, it was not compressed. Some of these engines were used to drive boats in the 1830s. They were called gas-vacuum engines.

Compression, as one of the occurrences required for practical efficiency of engine operation, was first suggested by a frenchman Alphonse bea DeRochas. He described the five necessary events for engine operation in 1862. These five "events" were incorporated into a successfull engine in 1876 by a German engineer, Dr. Nicholas August Otto. The Otto four stroke cycle principle has been used in a majority of all gasoline engines built to date.

Other memorable pioneers hastened popular acceptance of the Otto-cycle engines. Gottlieb Daimler, credited with being the "father" of the automobile, developed a small engine that ran on a light oil fuel similar to the gasoline of today. Previously, engines had used coal gases or heavy oil, weighed as much as 1,100 pounds per horsepower, and ran at not over 200 RPM. Daimler's engine weighed only 88 pounds per horse-power and ran 800 RPM. With the achievement of this power to weight ratio the use of the internal combustion

engine began to spread rapidly. The first basic two stroke engine as we know it today was invented in 1891 by an Englishman named Day. It was a modification of the four stroke cycle. By pressurizing the crankcase the intake and exhaust were accomplished without requiring strokes of the engine. The only strokes remaining necessary for engine operation were the compression and power strokes, hence the two stroke cycle.

By 1900 there were workable four stroke cycle and two stroke cycle engines. The chief accomplishments of the past century have been scientifically engineered refinements, refinements that have taken millions of manhours of study and labor to develop.

The word engine is defined as: a machine designed to transform potential energy into mechanical work. Engines that we are concerned with "burn" a fuel to turn a crankshaft and do work.

Energy is the indefinable something that puts "life" into matter - gives it warmth, light, and motion. We cannot see energy; we cannot weigh it or measure it in terms of how much space it occupies, yet it does exist. It is as real as the warmth and light of a fire, the electrical spark that jumps the gap of a spark plug, or the turning of a wheel.

Because we can see, feel, taste, or hear the effects of energy in different ways, we say there are five common active forms of energy.

Heat Energy - Warmth
Light Energy - Light and color
Kinetic Energy - Motion or movement
Electrical Energy - Shock or magnetic effect
Chemical Energy - Change brought about in one substance by another

Energy cannot be created or destroyed. It can only be changed from one form to another. For instance, a piece of wood disappears in flames and we think of it as completely gone. But the matter that was wood has combined

with air and formed an equivalent quantity of ash, water, and gases. As this change took place light from the flame and heat from the gases could be seen or felt. The change is not always this obvious. Because we do not know how to release the energy from most forms of matter, we refer to it as hidden, and call it latent energy. Whenever we do isolate a form of matter from which we can release part or all of the energy, we say that it contains potential energy, for we have learned how to release a small part of the energy stored in these substances. It is the potential energy of crude oil derivatives (gasoline, diesel, kerosene and propane) that our engines are designed to release and to convert into mechanical work.

In its mechanical sense, work is the useful movement of some object. When an object weighing one pound is raised a distance of one foot the effort accomplished one foot pound of work. Work accomplished is expressed in foot pounds. Machines have the capacity to move an object continuously, not just one certain distance. Such a machine is said to produce mechanical power. Mechanical power is rated in terms of the foot pounds of work that the machine will accomplish on one second.

We also use the term horsepower (hp) instead of foot-pounds per second. By definition, 1 hp = 550 ft-lb per second or 33,000 ft-lb per minute. This amount was established by James Watt. When he invented the steam engine he wished to equate his engines with the horse which was the prime source of power at the time. The term may not be entirely accurate but has enjoyed popular usage for so long that it is not likely to be changed.

A combustion engine is defined as one that uses the heat energy of fuel. They are also called heat engines. There are said to be two types: external combustion engines and internal combustion engines. The external type uses

the heat energy released from the fuel to heat some medium through which force is applied to the piston in the cylinder. Water or water vapor (steam) is the medium in the case of the steam engine. The internal combustion engine burns its fuel (gasoline, gas or oil) inside of the cylinder in such a manner that the expanding gases from the burning fuel becomes the medium that applies force to the head of the piston. When the potential energy in the fuel is released by the burning, it manifests itself in three forms - light energy, heat energy, and kinetic energy. The light energy is negligible and is useless to the engine. The heat energy is considerable, temperatures up to 4,000° F are possible inside a running engine. This heat does serve a useful purpose though we utilize only a portion of it. Most of it is excess and actually becomes a hinderance. One of the major problems of the internal combustion engine is dissipation of the excess heat.

There are two methods that can be used to change some matter from one form to another. Heat is one of these methods. Pressure is the other one. Both methods are utilized in an engine. Pressure is used to make the fuel-air mixture more combustible and the heat from combustion causes the gases to expand providing the kinetic energy necessary to move the piston. Whether or not a substance is heated sufficiently to change state, heating it does result in its expansion. Some substances which either oxidize very very slowly, or not at all under normal temperatures, will oxidize quite rapidly when they become hot enough. The accelerated oxidation, or burning, is also called combustion. Substances which will oxidize or burn in this manner are said to be combustible or flammable, and are referred to generally as fuels. The temperature at which such a substance will start to burn is called its kindling point, or its ignition point.

One method of raising the temperature of a fuel to its kindling point is to ignite it by bringing it into contact with something that is already burning and therefore releasing considerable heat. Another method is to raise the fuels temperature by compression. Compression is reducing the space that a substance occupies. In general, for every pound of pressure exerted there will result an increase in temperature of 2° F. Therefore, if the compression is sufficient, the temperature of the substance will rise. If the additional heat does not escape fast enough, the substance will reach its ignition point. To this add the fact that combustion takes place in a confined space. The heat is confined so that it builds to a very high temperature - enough to change most of the fuel present to its gaseous state, even to superheat these gases so that their tendency to expand suddenly becomes more than enough to break out of the confined area with a violence that we call an explosion. In an engine the breaking out is accomplished by pushing the piston downward away from the combustion chamber.

Now that we have reviewed the principles involved in combustion engines we can say that in order for an internal combustion engine to operate only requires four things. The four things are air, fuel, compression and ignition.

Air - to provide the oxygen necessary for combustion.

Fuel - to provide the heat energy to operate the engine.

Compression - to increase pressure of combustion.

Ignition - to cause combustion to occur at the time required.

The mechanical devices and apparatus on the engine are designed to facilitate and control the interaction of these four items. The air fuel ratio is controlled by the carburetor. The carburetor is one of the most important devices on the engine. It is the heart of the fuel system.

Basic Carburetor Theory And Terms

The fuel system does several jobs such as storing the raw fuel and supplying the combustible air-fuel mixture to the combustion chambers of each cylinder. The system consists of the fuel tank, fuel lines, fuel pump, fuel filter or filter, carburetor, air cleaner and intake manifold.

Fuel filters may be located in the fuel tank or lines, the fuel pump, or on the carburetor. They remove rust and other foreign particles that may accumulate in the fuel tank or lines and which would clog or affect the operation of the carburetor jets or the float needle and seat. Fuel filters may include a sediment bowl and/or a ceramic, metallic or treated paper filtering element.

The fuel pump moves fuel from the gasoline tank to the carburetor. It must supply adequate fuel for engine requirements ranging from idle to full speed and during periods of sustained full acceleration.

Purpose of a Carburetor

Engines will not run on "liquid" fuel. A metering device must be used to mix fuel and air in proper proportions to accommodate all different types of starting and driving ranges. Example: cold or hot starting, idle, part throttle, acceleration and high speed operation. The carburetor performs this function.

The formation of the air/fuel mixture consists of subdividing or atomizing the fuel and mixing the finely divided particles of fuel with air. Atomization is accomplished by adding air to the liquid fuel as it

moves through the carburetor passages and then spraying this air/fuel mixture through nozzles or jets into a stream of moving air which is flowing into the intake manifold. This air/fuel mixture must then be converted into vapor before it is introduced into the combustion chamber of the engine. The vaporization is assisted by the heat of the intake manifold.

Variations in speed and load conditions demand a different volume of air and a corresponding difference in fuel volume. The mixture ratio, however, must be kept within flammable limits if combustion is to occur. The primary object of the carburetor is to produce the desired ratio for any operating condition.

COMPRESSION RATIO MODIFICATION

A good approximation to the compression ratio of an internal combustion engine is the ratio found by dividing the compression chamber volume (V_c) into the sum of the compression chamber volume and the displacement volume (V_d).

i.e. compression ratio (r)

$$r = \frac{V_c + V_d}{V_c}$$

EXAMPLE:

If the compression chamber volume (V_c) is 2½ cu. in. and the displacement volume (V_d) is 17½ cu. in., then the compression ratio, (r) would be:

$$r = \frac{V_c + V_d}{V_c} = \frac{2\frac{1}{2} + 17\frac{1}{2}}{2\frac{1}{2}} = \frac{20}{2\frac{1}{2}} = \frac{8}{1}$$

that is the value of the compression ratio would be 8 to 1.

Many engine manuals list the value of the displacement volume (V_d) but seldom give the compression chamber volume (V_c), so we need a practical way to measure V_c. If the displacement is given in cubic inches (cu. in.) then we may either measure V_c in cu. in. or in cubic centimeters (cc). (It should also be know that a cc is the same as a milliter (ml). The question of using cu. in. or cc to measure V_c would be settled by the type of measuring device you use to determine V_c.

A scheme for measuring V_c would be to remove the head, block all holes, (valves, spark plug, etc.) then turn it with the gasket surface uppermost and level. From a "suitable source" pour enough light oil, diesel fuel, or other fairly safe liquid to just fill the compression chamber. Now, what is a "suitable source"? Well, any sort of graduated cylinder, test tube, pitcher, measuring cup, etc. that has accurate enough markings to enable you to know how much liquid you poured into the compression chamber to just fill it. That is; know how much you start with in your "suitable source", (either cu. in. or cc) and read how much is left after you fill the compression chamber. (DO NOT SPILL ANY!! IF YOU DO, START OVER.) Your compression chamber volume (V_c) will be the amount you start with minus what is left after the pour. For example, if you start with a full 50 cc graduated cylinder and pour the compression chamber full and have 18 cc left in the graduated cylinder, this would mean you have a compression chamber volume of 50-18 OR 32cc.

If the known displacement of the cylinder is say 21.3 cu. in., you will need to convert 32 cc to cu. in. (All measurements used in formulas must be in the same type of units, metric or conventional.) For a multi-cylinder engine, divide the total displacement of the engine by the number of cylinders to obtain the displacement of one cylinder. To convert cc to cu. in., you divide the number of cc by 16.387. In our example: 32 ÷ 16.387 would be 1.953 cu. in. giving a compression ratio (r) of $\frac{1.953 + 21.3}{1.953}$ = 11.906 or about 12 to 1. (pretty good for alcohol.)

If the displacement should be given in cc, measure the value of V_c in cc and use compression ratio OR, with V_d in cc and if you measure V_c in cu. in. then you multiply the value of V_c in cu. in. by 16.387 to get V_c in cc. For example: If V_d = 270 cc and you measure V_c as 2.3 cu. in., the value of V_c in cc would be 2.3 X 16.387 OR 37.690 cc and the compression ratio would be:

$$r = \frac{37.690 + 270}{37.690} \approx 8.16, \text{ about 8 to 1.}$$

If you do not have the displacement given then you could measure the value of V_d by pouring, as in measuring the value of V_c. (Make certain the piston is at BDC when you measure.) It is also possible to determine the value of V_d by taking two measures--the bore (b) and the stroke (s) and use the formula:

$$V_d = \frac{\pi b^2 s}{4} \text{ OR } 0.785\ b^2 s$$

For example: If you measure b = 2 3/4 in. and s = 3 1/4 in. then

$$V_d = \frac{\pi b^2 s}{4} \text{ OR } 0.785\ b^2 s = 0.785\ (2\ 3/4)\ (2\ 3/4)\ (3\ 1/4)$$
$$= 0.785\ (2.75)\ (2.75)\ (3.25)$$
$$= 19.29 \text{ cu. in.}$$

or in common fractions $0.785 \approx \frac{157}{200}$

so: $V_d = \frac{157}{200}\ (11/4)\ (11/4)\ (13/4) = \frac{246,961}{12,800} \approx 19.29$ cu. in.

If you want to modify your engine to increase the compression ratio, you may want to know the effect on the compression ratio of "shaving the head" a certain amount, say "X." Where r is the approximate compression ratio you end up with, b is bore, s is stroke and V_c is compression volume.

$$r = 1 + \frac{b^2 s}{1.272\ V_c - b^2 x}$$

If we have: V_c = 80 cm, b = 8cm, s = 12 cm and X = 0.125 cm (NOTE: 1 in. = 2.54 cm and 1 cm = 0.394 in.) then:

$$r = 1 + \frac{b^2 s}{1.272\ V_c - b^2 x} = 1 + \frac{(8)^2\ (12)}{1.272\ (80) - (8)^2\ (0.125)}$$

$$= 1 + \frac{64\ (12)}{101.76 - 64\ (0.125)} = 1 + \frac{768}{101.76 - 8}$$

$$= 1 + \frac{768}{93.76} \cong 1 + 8.19 \cong 9.19$$

OR a final compression ratio of about 9 to 1 where the compression ratio before the shave would have been about 8½ to 1.

Another example: V_c = 5 1/3 cu. in., s = 2 1/2 in., b = 5 in. and X = 0.040 in.

$$r = 1 + \frac{(5)^2\ (2\ 1/2)}{1.272\ (5\ 1/3) - (5)^2\ (0.040)}$$

$$r \cong 1 + \frac{25\ (2.5)}{1.272\ (5,333) - 25\ (0.040)}$$

$$r \cong 1 + \frac{62.5}{6.784 - 1} = 1 + \frac{62.5}{5.784}$$

$$r \cong 1 + 10.806 \cong 11.806$$

OR about 12 to 1 where the original compression ratio would have been about 10 to 1.

One last example would be the case of where we know the present compression ratio and/or dimensions and would like to estimate the amount of material that would have to be removed from the head to give a specific higher compression ratio.

Let's say the initial conditions are: present compression ratio is about 9 to 1, V_c = 1.75 cu. in., b = 2.25 in., and s = 3.5 in. Let's see how much cylinder head "shave" (X) it would take to get C R equal to about 12 to 1.

Now: $$X = \frac{1.272\ V_c}{b^2} - \frac{s}{CR - 1}$$

where X is the "head shave" and C R is the desired compression ratio.

$$X = \frac{1.272\ (1.75)}{(2.25)^2} - \frac{3.5}{12 - 1}$$

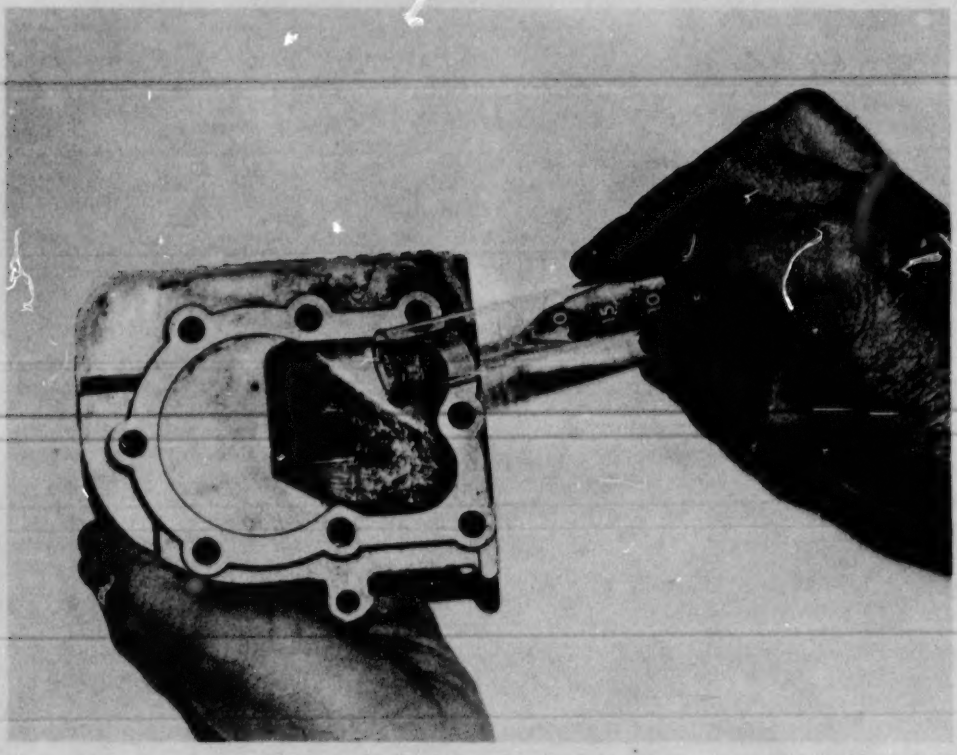
$$X = \frac{2.226}{5.0625} - \frac{3.5}{11}$$

$$X \cong 0.4397 - 0.318$$

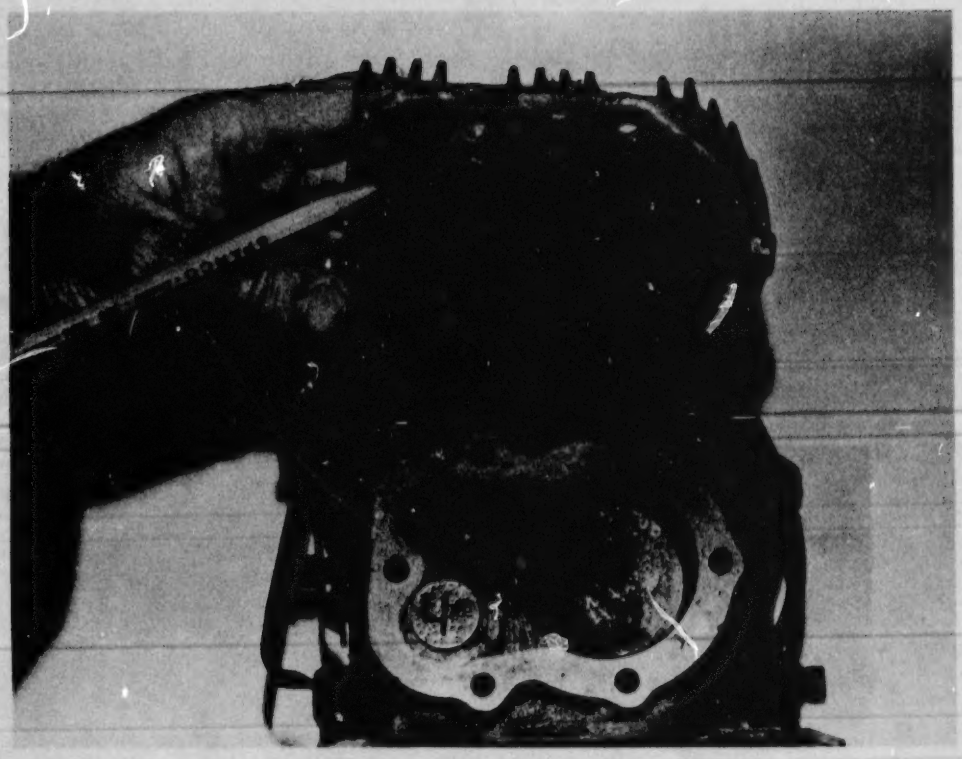
$$X \cong 0.1217 \text{ in. OR ABOUT } 1/8 \text{ in.}$$

(WHICH MAY BE TOO MUCH TO SHAVE.)

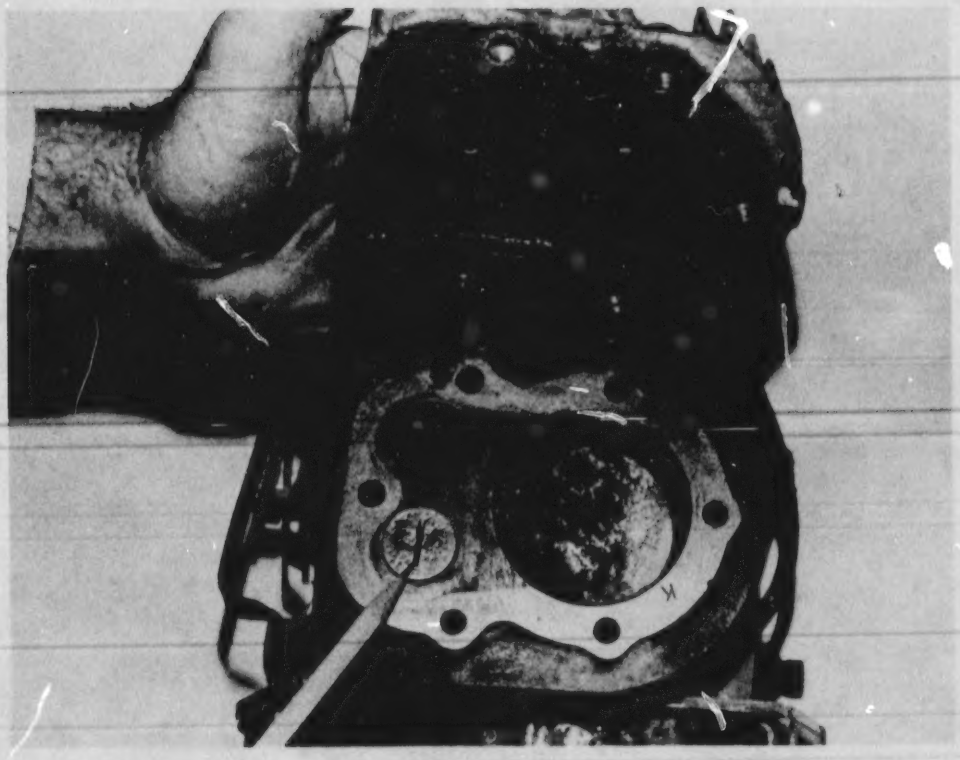
Remember that most of the given calculations will give only approximate answers because of such factors as the fact that we are dealing with measurements, combustion head design, and thickness of head gasket, etc.



A METHOD OF MEASURING VOLUME OF THE COMBUSTION CHAMBER.



COMBUSTION CHAMBER DESIGN PROVIDES CLEARANCE FOR VALVES.



ANY MACHINING OF HEAD TO INCREASE COMPRESSION RATIO MUST TAKE INTO ACCOUNT VALVE LIFT.

STATE FAIR COMMUNITY COLLEGE
1900 Clarendon Road
Sedalia, Missouri

June 18, 1980

ETHANOL - GASOLINE CONSUMPTION COMPARISON

TEST CONDUCTED BY: Automotive Technology Department
GLEN MISHLER
BILL SPIGNESI

VEHICLE IDENTIFICATION:

Make - Ford Model - 1974 Econoline 200
Engine - 302 Cubic in.
Compression Ratio 9-1
Bore 4.00 in. x 3.00 in. Stroke

VEHICLE WEIGHT - 4,830

VEHICLE CONDITION:

IDLE RPM 650D
IGNITION TIMING 6°BTDC on Gasoline
12°BTDC on Ethanol

TEST CONDITIONS:

OUTSIDE TEMP. 85° F

TEST RESULTS:

Gasoline - Regular Grade Leaded
Carburetor - Stock Autolite Model 2100 2v

30 miles per hour 18 miles per gallon
40 miles per hour 18 miles per gallon
55 miles per hour 11 miles per gallon

Ethanol - 189 Proof
Carburetor - Stock Autolite Model 2100 2v
Modified For Ethanol
With Spignesi - Mishler system of modification
Ignition Timing - 6° BTDC

(cont'd)

30 miles per hour	12 miles per gallon
40 miles per hour	10 miles per gallon
55 miles per hour	8 miles per gallon

IGNITION TIMING - 12 BTDC

30 miles per hour	10 miles per gallon
40 miles per hour	13 miles per gallon
55 miles per hour	10 miles per gallon

This was a preliminary test to determine performance and fuel consumption. Time did not permit any effort to determine long range effect of using ethanol as the sole fuel in the engine.

We felt that further refinements in tuning the engine could be accomplished. The engine timing change indicated the distributor spark advance curve should be modified for use with ethanol.

No information on effects of long term use of ethanol on spark plugs, valves and other engine components has been determined. This will require considerable time and extensive testing to compile any data in these areas.